

# Advances in Visual Aids to Navigation Technology

*Leveraging technology to improve navigational aid performance and reduce risk.*

by MR. ROBERT TRAINOR  
U.S. Coast Guard, Office of Navigation Systems



## Navigation

Since the first known lighthouse in Alexandria, Egypt, visual aids to navigation have been established throughout the world to help mariners determine their positions, guide their ships to the great ports, and to warn them of hazards. In North America, the first recorded visual aid to navigation was Boston Light, built on Little Brewster Island in 1716.<sup>1</sup>

Cask and spar buoys deployed in the Delaware River and Boston Harbor in the late 1700s were probably the first registered floating aids to navigation in America.<sup>2</sup> Today's aids to navigation share the same purpose as that ancient lighthouse in the Mediterranean (Figure 1) and those early North American aids—promoting safety at sea. While their purpose hasn't changed much over time, the aids themselves and how they're serviced and maintained certainly has, especially over the past three decades.

The U.S. Coast Guard, per United States Code 14USC81, administers the United States aids to navigation (AtoN) system and is responsible for its development, establishment, operation, and maintenance. The Coast Guard has consistently sought new equipment, techniques, and methods to provide all waterways users with a reliable, cost-effective system of aids to navigation that will enable them to fix their vessels' positions, determine safe courses to steer, and avoid unseen dangers to the degree of accuracy appropriate to the level of risk.<sup>3</sup>

To the casual observer, the buoys and beacons along our nation's coasts look pretty much the same as they

did 30 years ago, except perhaps that black buoys are now green and the black and white (skunk) mid-channel buoys are now red and white. A little closer look, however, will unveil that an extensive and ongoing technological transformation is taking place, not just on the buoys and beacons themselves, but with servicing and maintenance practices as well.

### Is the Buoy Where the Coast Guard Says it Is?

Determining an accurate geographic position at sea has challenged mariners since human-kind first ventured off land. The accuracy of an aid to navigation's geographic position is important to professional mariners and casual boaters alike because they all depend on these aids to help them determine their position.

Until the late 1970s, the instruments, methods, and techniques of positioning floating aids to navigation hadn't really changed much since the days of sail (Figure 2). The most accurate way to position a buoy

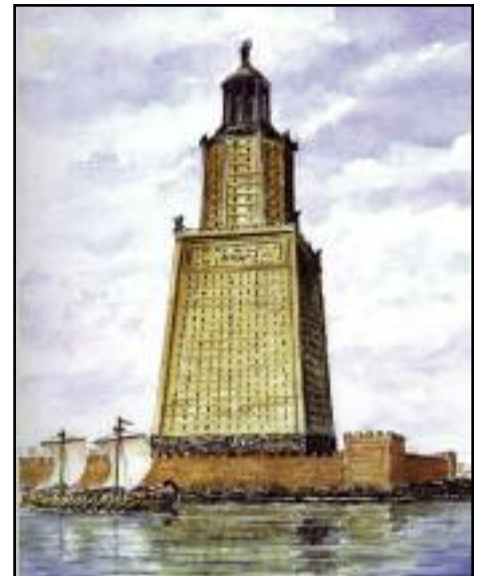


Figure 1: "Der Pharos in der Vorstellung des Vertassers," artist's rendition of the Pharos of Alexandria Lighthouse.<sup>4</sup>

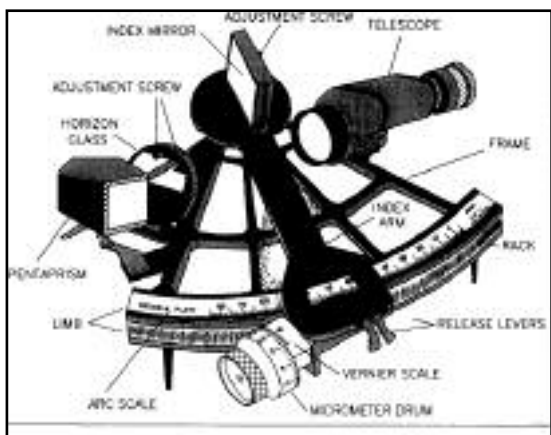


Figure 2: Drawing of a survey sextant, the primary aids to navigation positioning instrument prior to differential global positioning system technology. USCG graphic.

the black dot of the buoy's chart symbol, then the buoy was considered to be on "charted position." The fix was checked by adding at least one more LOP, such as an angle, bearing, or range.<sup>5</sup>

But was the buoy really where it was plotted? While instruments used to position buoys had slowly improved over the years, the process still contained inherent errors. For example, observations of the

same sextant angle often varied between different sextants as well as between different personnel. Cartography had also improved over the years, but the chart was still only as good as the printing press, the ink, and the paper it was printed on. Varying chart scales, editions, and conditions greatly affected the accuracy of plotting a fix in relation to the black dot. For example, on a 1:40,000-scale chart, the black dot's diameter represents about 27 yards. The buoy might plot in the black dot, but where was its anchor (sinker)? And would the buoy still be on charted position with a change in tide or current?

In some cases the position of the black dot on the chart varied from one

chart edition to the next. If the buoy's black dot could move, then so could the symbols for the objects that were used to obtain the fix. To add to these potential inaccuracies, observer offset (the distance and bearing from the angle-taker to the buoy) and buoy excursion (the distance and bearing from the buoy to the sinker's position) were not adequately considered when plotting the fix. The aggregate of these inaccuracies meant that there was a fairly good chance that the buoy was not actually set where it had been plotted. Setting an entrance or sea buoy within 30, 50, or even 100 yards of its charted position might not pose a significant risk to the mariner, but closer to shore, where channels are typically narrower, traffic heavier, and hazards closer aboard, even a 20-yard error could lead to disaster.

Recognizing the problem, the Coast Guard commissioned a study in the mid-1970s to improve its capability to position aids to navigation by researching and applying available technology. This led the Coast Guard to implement new positioning methods that facilitated stricter, more accurate positioning standards. Some of these improvements included:

- Replacing the term "charted position" that previously defined an aid's position with an "assigned position" (AP). The AP definition eliminated errors introduced by chart inaccuracies by assigning a specific geographic location expressed in latitude and longitude with accuracy to the thousandths of a second.
- Accuracy classifications were developed for buoys. For example, an aid within the area expressed as the radius of a circle in yards around the AP of an aid to navigation is considered to be "on station."<sup>6</sup>
- Three-arm protractors were replaced by a computer program that accounted for observer offset and excursion and trapped other potential inaccuracies. Instead of plotting the fix on a paper chart, the computer program took into account many of the possible inaccuracies and delivered a "most probable position" (MPP) solution of the buoy's sinker expressed in latitude and longitude, the range and bearing from most probable position to assigned position, and whether or not the buoy plotted on station.
- Better documentation, training development and delivery, and distribution of new positioning equipment to servicing units.



Figure 3: A lighted buoy, before solarization. USCG photo.

While these efforts significantly improved the Coast Guard's AtoN positioning performance, a lack of a sufficient number of surveyed objects in certain areas and poor visibility, due to weather and darkness, still hampered this process. So in the continuing effort to improve the process of positioning aids to navigation, the Coast Guard built on the Department of Defense's global positioning system (GPS) technology, and by the early 1990s had developed and deployed the differential global positioning system (DGPS). Today, the Coast Guard is able to position most aids to navigation in virtually any condition of visibility, day or night, with an unprecedented degree of accuracy.<sup>7</sup>

DGPS integrated with the automated aid positioning system computer software has significantly improved AtoN positioning accuracy. The cumulative result of these efforts has enabled the Coast Guard to confidently answer, "Yes, the buoy is set where we said it was set." In addition to promoting waterway safety by providing the mariner with a more reliable signal, these improvements have considerably enhanced the efficiency of positioning buoys, freeing up valuable Coast Guard assets for other waterway safety and homeland security missions.

### Tapping Into the Sun's Energy

By the late 1960s, light signals on buoys and beacons had already undergone significant improvements (Figure 3). Gone were lead acid batteries; mechanical flashers; four-place, gear-driven lampchangers; and bulky glass lenses. These were replaced by air-depolarized primary batteries (batteries that once expended could not be economically recharged); solid-state flashers; six-place, spring-loaded lampchangers; and acrylic molded lenses. Although pleased with these improvements, the Coast Guard was not content, and continued numerous initiatives to improve aid signal efficiency and reliability. One of these initiatives aimed to introduce solar power into the aids to navigation system.

Buoys have always relied on natural sources of energy to power their sound signals. The restless motion of the sea causes tappers to strike a sound buoy's bell, to produce a distinguishable sound signal. Similarly, whistle buoys operate with air generated by the buoy moving with the rising and falling motion of the sea. Tapping into the sun's energy to power light signals, by comparison, is a comparatively recent development in maritime aids to navigation.

Prior to the Coast Guard's solar program initiative, air-depolarized primary batteries powered lighted aids. These primary batteries required replacement every 12 to 36 months, depending on the light's char-

acteristic and nominal range. Replacing the batteries, or "recharging an aid," was a time-consuming and laborious undertaking. For example, when a lighted buoy required recharging, it was typically hoisted aboard a buoy tender (ranging from a 65-foot inland buoy tender to a 180-foot seagoing buoy tender), depending on the buoy and mooring size. Once securely aboard, the buoy's battery pocket was accessed, the 215- to 508-lb. battery rack was removed, a new battery rack was inserted, the pocket was resealed, and the seal verified via an air test. For a large buoy, the entire process could take several hours. In addition to the time and effort required to recharge aids to navigation, the annual hazardous waste in the form of expended batteries was approximately 950 tons nationwide.

In terms of improving servicing and logistics efficiency, converting even half of the nation's lighted aids to navigation to solar power promised a tremendous return on investment. For example, a lighted buoy before conversion to solar power, with a particular lamp size and characteristic, located on the Gulf Coast, required that a buoy tender replace the 508-lb. primary battery rack (containing 10 three-cell primary batteries) every two years. That same buoy after conversion to solar power would need just one 35-watt solar panel and two 60-lb. rechargeable solar batteries, which, under normal conditions, wouldn't need replacement for five years. Also, once an external battery box was developed, a three-person aids to navigation team would be able to recharge most lighted buoys in protected waters more economically and efficiently than a cutter could.

The Solar Initiative Program was launched in 1983, with a goal to convert approximately 10,000 Coast Guard lighted aids to navigation (nearly 60 percent of the total) from primary batteries to solar power. In just five years that goal was achieved and "solarization," as the con-



Figure 4: A solarized mid-channel buoy. Note the solar panels and single red sphere topmark. USCG photo.



Figure 5: A Coast Guard construction tender putting the finishing touches on a new solar-powered lighted beacon. USCG photo.

version effort came to be called, continued unabated, resulting in over 16,000 (about 94 percent) of the Coast Guard's lighted AtoN converted to solar power (Figures 4 and 5). The program is not over yet, as Coast Guard ocean engineers continue to develop solar solutions for the remaining six percent.

In addition to streamlining servicing procedures, the Solar Initiative Program has enhanced the Coast Guard's commitment to protecting the environment by significantly reducing its generation of hazardous waste. Since solar batteries are recycled after their useful life span (and so

avoid hazardous material disposal fees), the Coast Guard saves approximately \$576,000 annually.

### What's New With Light Signals on Aids to Navigation?

Technological advances for lighting equipment, a critical component of nearly 50 percent of the nation's visual aids to navigation inventory (not including western river buoys), have also been realized. Coast Guard ocean engineers have teamed up with aids to navigation operators to actively explore and implement new technologies to improve the performance of these light signals. One of the more recent initiatives is the deployment of light-emitting diodes (LED) lighting equipment on maritime aids to navigation (Figure 6).

The primary advantages of LEDs are that they last 100 times longer than incandescent lamps and use a fraction of the power to emit similar light intensity. Both of these advantages provide the opportunity to deploy self-contained LED lanterns on lighted buoys and beacons. These self-contained LED lanterns encase a battery, solar panels, and light into one unit. Currently the Coast Guard is experimenting with several different types of these self-contained LED lanterns that weigh between 12 and 48 lbs., are slightly larger than a football, and can be programmed to emit a specific light characteristic consistent with any of the Coast Guard's standard light rhythms.



Figure 6: A foam buoy equipped with a self-contained LED light, marking a wreck in Yaquina Bay, Ore. Courtesy of [www.solarmarinelights.com](http://www.solarmarinelights.com).

The anticipated longevity, reliability, and portability of these self-contained LED lanterns could enable the Coast Guard to increase servicing intervals, reduce buoy footprint (a lighter smaller lighting package may not require the support of the large steel buoy that was designed to carry much heavier loads), and employ smaller servicing units.

These examples of technological advances in visual aids to navigation hardly tell the whole story. Improved buoy coatings, lighted ice buoy improvements, non-ferrous buoy hulls, programmable flashers, five-year dayboard film, more efficient long-range lights, day/night centerline ranges, fog detectors, remote monitoring systems, and many other initiatives are all examples of leveraging technology to improve navigational aid performance.

While our maritime aids to navigation system has changed over the past 30 years, one thing hasn't—the Coast Guard's continued commitment to provide safe passage for all waterway users.

### About the author:

Mr. Robert Trainor is an aids to navigation specialist in the U.S. Coast Guard Office of Navigation Systems, Visual Navigation Division. He previously spent 31-plus years serving on active duty. His duty assignments included tours as commanding officer of two Coast Guard buoy tenders as well as numerous other aids to navigation-related positions. His first buoy tender assignment was in 1976 aboard the USCGC Rambler, whose homeport was in Mobile, Ala.

### Endnotes:

- <sup>1</sup> "Historically Famous Lighthouses," USCG Publication (CG-232), 1972.
- <sup>2</sup> U.S. Coast Guard, "A History of Buoys and Tenders," by Amy K. Marshall.
- <sup>3</sup> U.S. Coast Guard, "Short-Range Aids to Navigation Strategic Plan," 2006.
- <sup>4</sup> Artist's rendition courtesy of [www.btinternet.com](http://www.btinternet.com).
- <sup>5</sup> Aids to Navigation Manual (CG-222), 1964 edition (Amend 2).
- <sup>6</sup> Aids to Navigation Manual (COMDTINST M16500.1C), 1996.
- <sup>7</sup> The advertised accuracy tolerance of DGPS is 10 meters, but typically delivers tolerances to within one to three meters.